PRELIMINARY PROPOSAL FOR FY 2005 FUNDING

Title: Three-Dimensional Behavior and Passage of Juvenile Salmonids at The Dalles Dam, 2005.

Study Codes: SBE-P-00-17

Principal Investigators: Kenneth M. Cash and Noah S. Adams

Project Leader: Dennis W. Rondorf

Address: U.S. Geological Survey
Columbia River Research Laboratory
5501A Cook-Underwood Road
Cook, WA 98605
(509) 538-2299; FAX (509) 538-2843

Principal Investigators: Derrek M. Faber and Mark A. Weiland

Project Leader: Thomas J. Carlson

Address: Battelle, Pacific Northwest National Laboratory
PO Box 999
Richland, WA 99352
(503) 417-7562

Submitted to: U.S. Army Corp of Engineers
333 SW First Ave
PO Box 2946 97204-3495
(503) 808-4780

Administrative Contact: Michele F. Beeman, USGS
U.S. Geological Survey
Columbia River Research Laboratory
5501A Cook-Underwood Road
Cook, WA 98605
(509) 538-2299; FAX (509) 538-2843
Al Garcia, Battelle
PO Box 999
902 Battelle Blvd.
Richland, WA 99352
(509) 372-2954

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PROJECT SUMMARY

RESEARCH GOALS

The U.S. Geological Survey and Battelle have been involved in monitoring and evaluating many of the developments in surface bypass that have been implemented throughout the Columbia River Basin. Since 1995, we have used state-of-the-art technologies to gather previously unattainable data on fish behavior and movement. One technology that has been very useful for pre- and post-evaluations of surface bypass structures is three-dimensional acoustic telemetry. We have successfully applied this technology at Lower Granite, Bonneville, Cowlitz Falls, Grand Coulee and The Dalles dams to gather data critical to the development of the surface bypass concept. In 2004, five 3-D systems were operated concurrently by USGS and PNNL during spring and summer studies at The Dalles Dam. We released 1200 fish implanted with acoustic tags (375 spring chinook salmon, 375 steelhead, 75 sockeye salmon and 375 sub-yearling, chinook salmon) in the John Day Dam tailwaters. We have completed post-processing 825 fish using newly developed auto-processing software which has cut processing time by more than 50%. We have already identified several consistent behavoirs described by the 3-D data.

In 2005, the U.S. Army Corps of Engineers is proposing to gather additional data to determine the feasibility of applying surface bypass concepts in the forebay of The Dalles Dam. The COE currently owns all of the equipment necessary to complete the study addressed in this proposal. The system manufactured by Hydroacoustics Technologies Inc. (HTI) is the only system that utilizes a transmitter suitable for implantation in juvenile salmonids. This system has been used at Rocky Reach Dam in 1998-2000, was part of our feasibility test conducted at Lower Granite Dam in 1999 and was fully implemented in 2000, 2001, 2002, and 2003 (Cash et al. 2001; Cash et al. 2003, Steig et al. 1998). The USGS and PNNL 3-D study at The Dalles Dam in 2004 indicated that the HTI system is fully functional and capable of producing the type of 3-D information needed to meet the research needs at The Dalles Dam in 2005 (See Appendix B. for description of HTI 3-D system).The goals of this study are to:

-Observe the three-dimensional behavior of acoustically tagged juvenile salmonids as they approach The Dalles Dam.

-Examine what stimuli migrant fish respond to as they approach the sluiceway, turbines and spillway and what stimulus, if any, has the most influence on their behavior. (Flow is generally considered to be the dominant stimulus influencing migrant behavior.)

STUDY OBJECTIVES

Objective 1*:* Characterize juvenile salmonid behavior in the forebay of the Dalles Dam using three-dimensional telemetry techniques.

Objective 2: Characterize the forebay and passage distribution of juvenile salmonids at The Dalles Dam.

> *Note: These study objectives meet the research needs identified in SBE-P-00-17 objectives 2 and 3.*

METHODOLOGY

We propose to use a 3-D telemetry tracking system to examine the movements of acoustically-tagged fish as they approach The Dalles Dam. These data will be used to determine approach behavior and investigate the potential benefit of a forebay guidance structure and to characterize the performance of the ice and trash sluiceway as a passage alternative. The systems we propose would provide much finer detailed information, on a continuous basis, than standard radio telemetry and allow us to answer many of the questions that have previously been left to speculation.

The one-of-a-kind data obtained by using acoustic telemetry has played a critical roll in the development of the surface bypass concept throughout the Columbia River Basin. It is perhaps the best data we currently have available to understand fish behavior relative to the environmental conditions around hydroelectric dams.

RELEVANCE TO THE BIOLOGICAL OPINION

The relevance of this research to the operation of the Federal Columbia River Power System and Juvenile Transportation Program is discussed in the 1995 Biological Opinion, RPAs 69 and 86.

PROJECT DESCRIPTION

BACKGROUND AND JUSTIFICATION

In the past ten years, substantial efforts have been made to enhance the downstream passage of juvenile salmonids at main-stem hydroelectric dams on the Columbia and Snake rivers. Much of this effort has focused on optimizing spill conditions, enhancing existing surface bypass routes, and reducing turbine entrainment of downstream migrating salmonids. At the spillway, fish passage efficiency and survival for various spill levels has be studied extensively and some progress has been made at some of the dams (including The Dalles Dam) to optimize spill conditions for passage and tailrace egress (Allen et al. 2000; Allen et al. 2001). While much work has been conducted to attempt to enhance existing surface oriented passage routes, early work at The Dalles Dam sluiceway did not meet design expectations. The Dalles Dam does not have a system for screening the turbine intakes. Although preliminary work has been conducted to develop a screened turbine intake bypass system, implementation plans have been postponed while other passage alternatives are investigated. For example, steel plates that occluded the upper half of the turbine intakes have been evaluated as one potential passage enhancement alternative at The Dalles Dam. However, data indicate that theses plates did not dramatically reduce turbine entrainment rates (Johnson et al. 2002). The Army Corp of Engineers and regional managers are looking at new alternatives to increase passage efficiency and survival at The Dalles Dam. Critical to the success of these new endeavors is a clear understanding of the migration behavior of fish as they approach and pass the dam.

Although a substantial amount of data has been collected at The Dalles Dam, there is clearly an absence of some critical information that the COE and regional managers need as they attempt to make improvements at this facility. Information on vertical and horizontal distribution of fish throughout the forebay of The Dalles Dam is sparse (Ploskey et al. 2001a; Giorgi and Stevenson 1995). Studies designed to examine forebay approach behavior have been conducted, but sample sizes was small (Sheer et al. 1997; Holmberg et al. 1997). These studies tracked 266 radio-tagged yearling chinook salmon and 121 subyearling chinook salmon. Most fish began moving toward the powerhouse, often toward the east end, but a small proportion moved along the north part of the forebay to the spillway. A similar study in 1995 showed subyearling chinook salmon moved down the north shore or at mid-channel and entered the forebay at the east end of the powerhouse (Sheer et al. 1997). Passage efficiency and survival studies have also been conducted at that The Dalles Dam using radio telemetry and hydroacoustics, but they were not designed to get the level of detail needed to answer critical questions as new passage alternatives are explored. (Hensleigh et al. 1999; Beeman et al. 2003; Ploskey et al. 2001b; Moursund et al. 2001; Moursund et al. 2002).

Evaluations of the potential use of the existing sluiceway at The Dalles Dam as a passage alternative was evaluated many years ago (Nichols 1979 and 1980; Nichols and Ransom 1981 and 1982). Nichols (1979) found the sluice gates at the west end of the powerhouse had higher yearling salmon passage rates than did gates in the middle. Nichols (1980) recommended that the sluiceway be operated 24 h/d because noticeable numbers of smolts used the sluiceway at night, although highest passage was during daylight hours. Based on these and other data, the sluice gates at Main Unit 1 have been open 24 h/d to pass juvenile salmonids during spring and summer. The sluiceway has been operated like this for the last 20 years. More recent studies indicate that more can be done to optimize the efficiency of the sluiceway as a passage alternative.

Sluiceway passage at The Dalles Dam was, and still is, an indication that fish have a natural tendency to be oriented near the surface of the water and will often readily pass through surface-oriented passage routes (Smith 1974). This behavior has been exhibited at other dams on the Snake and Columbia rivers where a relatively large percentage of smolts have been passed through surface-oriented routes using a relatively small volume of water. For example, at The Dalles Dam during times of no spill, Willis (1982) reported that up to 40% of total smolt passage occurred through the ice-trash sluiceway that passed about 3% of total river flow. Similar results have been obtained at Ice Harbor Dam ice-trash sluiceway (Swan et al., 1997). Additionally, at Wells Dam, Johnson (1992) reported that about 90% of the smolts passing the dam went through the spillway that passed only 10% of total river flow.

Past studies at The Dalles Dam has provided useful data on fish passage and survival. As the region embarks on ways to further enhance fish passage and survival at this and other facilities, more data is needed. This study is designed to gather critical information needed to make these improvements.

PROJECT OVERVIEW

There are several hypotheses on how fish use flow as a cue during downstream migration. One hypothesis, although simplistic, is that fish follow the bulk flow. Another hypothesis which has recently received more attention, is that fish use turbulence (Coutant 1998) and or acceleration fields (Haro et al. 1998) as cues during downstream migration. We propose to collect fish behavior information and integrate it with flow data generated by the computational fluid dynamics (CFD) model. Detailed fish behavior and water velocity data can be used as variables to quantify (e.g., logistic regression) the relation between fish and flow. This data can also be used to validate CFD models, which in turn can be used to characterize flow fields under different operational scenarios. Our data, together with the validated CFD models can be used to develop predictive equations (like the Numerical Fish Surrogate simulation model under development by Goodwin and Nestler) for fish behavior upstream of surface oriented passage routes. Development of these types of predictive models is complex (however, there is no magic in the process) and they can not be done without empirical data as the foundation for developing the relation between fish and flow.

We propose to collect fish behavior data using 3-D fish tracking systems. We have conducted feasibility tests and four years of full deployment of these systems in the forebay of Lower Granite Dam and one year of full deployment with five 3-D systems in the forebay of The Dalles Dam. These tests have allowed us to work out many of the logistical difficulties inherent in using 3-D telemetry systems and have prepared us for full implementation of similar systems at other main-stem dams. In previous years, traditional fixed radio-telemetry has provided very useful information on the behavior of fish upstream of Columbia River dams. However, the continuous three-dimensional information on fish behavior upstream of these areas is difficult to obtain using traditional telemetry equipment and fish depth can limit range of detection. In previous studies conducted at Lower Granite Dam, 3-D data has described fish behaviors along structures that other technologies failed to detect or inadequately described. For example, we observed a high proportion of fish guiding along the trash-sheer boom, a relatively shallow structure attached to the dam between the powerhouse and spillway. A 3-D system would allow us to gather continuous data on fish as they move through The Dalles Dam forebay. Three-dimensional fish location data can then be used with CFD models to develop equations that could predict fish behavior relative to flow conditions and surface bypass alternatives upstream of the dam.

CURRENT STATUS

In 1999, the USGS was contracted by the Army Corps of Engineers (Portland and Walla Walla Districts) to conduct tests in the forebay of Lower Granite Dam designed to determine the feasibility of using 3-D telemetry systems to obtain fine scale fish behavior information. In 2000, 2001, 2002, and 2003 the use of 3-D systems was fully implemented at Lower Granite Dam and Bonneville Dam, powerhouse 1 (Cash et al. 2001; Cash et al. 2003; Faber et al. 2001). In 2004, five 3-D systems were operated concurrently by USGS and PNNL during spring and summer studies at The Dalles Dam. We released 1200 fish implanted with acoustic tags (375 spring chinook salmon, 375 steelhead, 75 sockeye salmon and 375 sub-yearling, chinook salmon) in the John Day Dam tailwaters. We have completed post-processing 825 fish using newly developed auto-processing software which has cut processing time by more than 50%. We have already identified several consistent behaviors described by the 3-D data (see Appendix A. for examples of behaviors)

The COE currently owns all of the equipment necessary to complete the study addressed in this proposal. The system manufactured by Hydroacoustics Technologies Inc. (HTI) is the only system that utilizes a transmitter suitable for implantation in juvenile salmonids. This system has been used at Rocky Reach Dam in 1998-2000, was part of our feasibility test conducted at Lower Granite Dam in 1999 and was fully implemented in 2000, 2001, 2002, and 2003 (Cash et al. 2001; Cash et al. 2003, Steig et al. 1998). The USGS and PNNL 3-D study at The Dalles Dam in 2004 indicated that the HTI system is fully functional and capable of producing the type of 3-D information needed to meet the research needs at The Dalles Dam in 2005 (See Appendix B. for description of HTI 3-D system).

OBJECTIVES AND METHODOLOGY

<u>Objective 1</u>: Characterize juvenile salmonid behavior in the forebay of the Dalles Dam using three-dimensional telemetry techniques.

> *Note: This study objective meets the research needs identified in SBE-P-00-17 objectives 2 and 3.*

<u>Rationale</u>

The Dalles Dam is unique in its layout and design and poses distinct problems for out-migrating juvenile salmon. Turbine and spillway routes have shown less than ideal survival in past years, and previous research has provided useful but limited data on juvenile salmon entry distribution into the forebay at The Dalles Dam. Radio-telemetry studies have observed a difference in approach distribution for spring and summer migrants. Summer migrants follow closer to the shorelines than spring migrants which follow the channel thalweg. Hydroacoustic studies have observed changes in diel passage distribution, and changes in passage distribution that are related to total project operations (Ploskey et al. 2001). However, the detailed movements of juvenile salmon in relation to dam operations within the region 400 m upstream of the spillbay is still poorly understood. This information is critical for the implementation of any plan that would use a behavioral guidance curtain to divert juvenile salmon from the turbine units, and into the spillway for passage.

The only means to protect downstream migrant salmonids at The Dalles Dam (TDA) presently are spillway and sluiceway operations because there are no in-turbine screens or smolt bypass system. Under these measures, fish passage efficiency is about 80-90% with the remaining 10-20% passing through the turbines. Survival estimates of 92-96% for spill, 92-93% for sluice, and 81-86% for turbine passage are among the lowest in the Columbia River Basin (Ploskey et al. 2001a). Thus, there is a definite need to improve passage conditions for juvenile salmon at The Dalles Dam.

We propose to use a three-dimensional (3-D) fish tracking system to examine the movements of acoustically-tagged fish as they approach and pass The Dalles Dam. Detailed data about the behavior of juvenile salmonids as they approach the dam is critical to the development of future juvenile passage improvements. These data can be used to determine the location and size of guidance structures. Recent studies have supported earlier research that indicated 20-40% of juvenile migrants pass The Dalles Dam through the sluiceway. Based on its high efficiency, the sluiceway is an ideal candidate for behavior study. Integration of hydraulic data and fish behavior data may provide information that could lead to improvements in fish passage not only at The Dalles Dam, but at many other sites in the Columbia River Basin.

The USGS and PNNL worked out many of the logistic difficulties conducting 3-D telemetry at The Dalles Dam by deploying and operating 5 sixteen channel 3-D receivers concurrently during 2004. Implementing a 3-D system in 2005 would validate data from previous years and provide much more detailed information on fish behavior, thereby allowing us to answer many of the questions that have previously been left to speculation. Specifically, a 3-D system would allow us to gather continuous data in three-dimensions on fish as they move through The Dalles Dam forebay. The 3-D fish information could be combined with CFD data to validate and develop predictive models for fish behavior relative to changes in flow characteristics near passage routes at The Dalles Dam.

Task 1.1: Finalize technical issues related to implementation of a 3-D positioning system to monitor the movements of juvenile salmonids upstream of The Dalles Dam.

> *Note: Because we have conducted feasibility tests in 1999 and fully implemented a 3-D system in the forebay of Lower Granite Dam in 2000, 2001, 2002, 2003 and operated 5 3-D systems concurrently at The Dalles Dam in 2004 most of the logistical difficulties inherent in implementing a similar system in the forebay of The Dalles Dam in 2005 have been overcome.*

Activity 1.1.1

Surgical implantation has been an effective method for acoustic tag attachment in previous studies, however due to the proposed sample size we will likely use gastric implantation. The gastric implantation method has relied on the antenna on radio tags to aid in the procedure (Adams et al. 1998). Since acoustic tags lack an antenna, a new methodology is required. We conducted laboratory tests in 2004 to test the feasibility of the gastric implantation method for existing acoustic

tags.
We found that it was feasible to gastrically implant acoustic tags in juvenile salmon with a tag-to-body-weight of 5%. Extending these tests with a larger sample size would facilitate the completion of the gastric implantation method for acoustic tags. This information is necessary for future research where larger numbers (>1200 tags) of acoustic tags must be used.

Schedule:

November through December, 2004.

Activity 1.1.2

Provide input and specifications to HTI, Inc. to assist the development of additional tools to streamline the use of the auto-processing software. At this time, we have post-processed and 3-D tracked 825 fish form the spring 2004 study. This is more than 4 times more data than previous studies. We will provide a preliminary report of the spring data by September 1st, which is 3 months earlier than previous preliminary reports. Further streamlining of the auto-processing system will facilitate near real-time viewing of 3-D data.

Schedule:

October through December, 2004.

Activity 1.1.3

Cooperate with The Dalles Dam project personnel to identify source of acoustic noise at the project. In 2004, we found a directional source of noise emanating from the middle of The Dalles Dam Powerhouse. Hydrophones in the immediate vicinity with a line-of-sight to the turbines were negatively affected while hydrophones nearby without a line-of-sight were not affected. The noise was most prominent during periods of high turbine operations and specifically when turbines on both ends of the powerhouse were on. We feel it prudent to isolate the source of the background noise at The Dalles Dam and consider actions to minimize impacts to 3-D data collection. This information will be used to identify and minimize sources of noise and adjust system configurations to ensure data quality.

Schedule:

January, 2005.

Task 1.2: Gather fish movement information at The Dalles Dam.

Activity 1.2.1

Install, calibrate, and test the 3-D underwater hydrophones at The Dalles Dam Appendix C contains one option for a hydrophone array. Other hydrophone arrays can be designed with reduce coverage and cost.

Schedule:

February through March, 2005.

Activity 1.2.2

Install, calibrate, and test autonomous hydrophones downstream of The Dalles Dam to confirm passage and calculate detection probabilities using ultrasonic telemetry.

Schedule:

February through March, 2005.

Activity 1.2.3

Determine release site, number of fish per release, and time interval between releases.

Schedule:

January, 2005.

Activity 1.2.4

Conduct releases of acoustically-tagged subyearling chinook salmon, yearling chinook salmon, steelhead, sockeye salmon and collect 3-D data in The Dalles Dam forebay during the spring and summer of 2005.

At this time we propose that a minimum of 1,200 acoustically tagged fish be released upstream of The Dalles Dam. The size of the current tag (0.75 g) allows us to implant them in subyearling chinook salmon, yearling chinook salmon, steelhead, and sockeye salmon. We propose to release 375 subyearling chinook salmon, 375 yearling chinook salmon, 375 steelhead, and 75 sockeye salmon.

Schedule:

April through July, 2005.

Activity 1.2.5

Coordinate with appropriate agencies to sequester, implant tags, and release steelhead smolts during the months of April, May, and July, 2005.

Schedule:

February through March, 2005.

Activity 1.2.6

Complete the necessary Endangered Species Act documentation and obtain the necessary permits and approval to work in the Columbia River.

Schedule:

December, 2004.

Task 1.3: Analyze juvenile fish behavior upstream of The Dalles Dam.

Activity 1.3.1

Work closely with statisticians and modelers (i.e., Andrew Goodwin, John Nestler and others) to integrate fish behavior information with modeled flow information. This integration will allow us to better define the flow characteristics influencing fish behavior upstream of The Dalles Dam and predict fish response to proposed structural modifications in the forebay.

Schedule:

May through August, 2005.

Activity 1.3.2

Determine approach distributions and behavior of fish along The Dalles Dam powerhouse and compare behavior upstream of the ice and trash sluiceway entrance with 3-D technology.

Fish movement adjacent to the sluiceway will be examined in detail using the existing fish tracking array. The 3-D fish tracking array will be deployed so that sub-meter resolution on fish positions will be acquired in a 30 m region adjacent to the sluiceway entrance. Alternative positioning technologies will also be tested so that fish movement and their subsequent response to flow stimulus may be better defined in this region.

Schedule:

June through September, 2005.

Activity 1.3.3

Confirm passage of fish detected in the The Dalles Dam forebay with downstream detection gates and compare detection probabilities between ultrasonic telemetry and radio telemetry techniques.

Schedule:

June through September, 2005.

Objective 2: Characterize the forebay and passage distribution of juvenile salmonids at The Dalles Dam.

Note: These study objectives meet the research needs identified in SBE-P-00-17 objectives 2 and 3.

Rationale:

The distribution and movement patterns of juvenile salmon will be compared to the hydroacoustic survey results from 2003. The forebay at The Dalles dam will be divided into grid sections of the same dimensions as those created for analyzing the fish movement and distribution using the hydroacoustic data. Within these grids, the total relative distribution and movement patterns of 3-D tracked juvenile salmon will be compared to the 2003 hydroacoustic survey results based on the sample of juvenile salmon that pass through each grid section during similar project operations. Any model evaluation of fish distribution and movement (i.e., the numerical fish surrogate model) may be compared in this exact manner in order to determine model performance to field results. Acoustic telemetry data and mobile hydroacoustic data will provide the necessary background support for any model assessments.

By tracking the movements of subyearling chinook, yearling chinook salmon, steelhead and sockeye salmon, we can determine passage through The Dalles Dam. This will allow us to calculate metrics such as Fish Passage Efficiency (FPE) and Spill Passage Efficiency (SPE). The integration of flow and fish behavior is needed to better understand the response of fish to different passage alternatives. For example, radio-telemetry data collected in 1998-1999 at Bonneville Dam indicated that fish appeared to come relatively close to the openings in the Prototype Surface Collector (PSC) but did not enter. A better understanding of water velocities upstream of surface bypass may help us better understand why more fish do not enter the structures and in turn may help lead to the design of more attractive openings. These same questions apply to the sluiceway at The Dalles Dam.

Task 2.1: Determine route and distribution of juvenile salmonid passage at The Dalles Dam powerhouse, sluiceway and spillway.

Activity 2.1.1

Calculate Fish Passage Efficiency (FPE), Spill Passage Efficiency (SPE) and other relevant metrics from the observed distributions (*Appendix C)*.

Schedule: October, 2004.

Activity 2.1.2

Evaluate 3-D , fixed hydroacoustics, and radio telemetry passage metrics to determine if results are comparable.

Schedule: October, 2005.

Task 2.2: Relate movement and distribution data obtained under objective 1 to similar data from mobile hydroacoustics collected in the spring and summer.

Activity 2.2.1

Compare species-specific distribution of acoustic-tagged fish to the population distribution provided by mobile hydroacoustics.

Schedule: October, 2005.

FACILITIES AND EQUIPMENT

The most significant costs required to meet study objectives will be the purchase of the 3-D transmitters. Divers and a crane barge will be necessary to deploy bottom-mounted hydrophones. It will be necessary to contract surveying of bottom-mounted hydrophones using multi-beam acoustics. Without this information, the 3-D data cannot be analyzed

The USGS operates the Columbia River Research Laboratory which includes research boats, vehicles, office space, and laboratory facilities for the conduct of this study. Boats will be operated at cost with no additional lease cost to the project. Boats will be operated by Department of Interior certified boat operators trained in CPR and First Aid. Boats will be inspected by a third party to meet U.S. Coast Guard standards. USGS will provide a quality control system consistent with the Good Laboratory Practices Act.

Other resources include:

-A selection of 25 boats up to 30 feet in length for work on the river.
-Two 2700 square foot storage facilities with a shop.
-4000 square foot wet lab facility.
-A local computer network integrating state-of-the-art GIS capabilities.
-A technical staff of 60-100 fishery biologists, ecologists, and GIS specialists.
-An office and analytical laboratory in a 15,000 square foot facility.

Battelle operates the Pacific NW National Laboratory for the U.S. Department of Energy in Richland Washington, which includes research boats, vehicles, office space and laboratory facilities. Boat operators are instructed under the U.S. Coast Guards Power Squadron, and all are trained in CPR and First Aid. Other resources include:

-Immediate access to technical experts in the fields of Engineering (Civil, Hydraulic, Electrical, Computer, etc.), Biology and Ecology.
-Experienced field and technical staff.
-Access to Journeymen Employees
-And a variety of state-of-the-art equipment.

IMPACTS

<u>Impacts to other researchers</u>

The use of acoustic tags in this project would not impact other radio telemetry studies in the Basin. In general, the proposed frequencies for use in the 3-D acoustic telemetry system will not impact other studies using single beam, split beam, or multibeam hydroacoustic systems. However, it will be necessary to separate 3-D hydrophones and active acoustic transducers >40 ft. and avoid pointing active acoustic transducers at the 3-D hydrophones.

COLLABORATIVE ARRANGEMENTS and/or SUB-CONTRACTS

This project will be completed as a collaborative effort between the USGS, Columbia River Research Laboratory and Battelle, Pacific Northwest National Laboratory. Staff from both laboratories are familiar with passive acoustic technologies and have completed previous collaborative projects at Columbia River dams.

Necessary sub-contracts include crane support to deploy hydrophone mounts on the powerhouse and divers to deploy hydrophones in open water areas near the powerhouse. In addition, a contractor with multibeam acoustic survey equipment will be needed to determine the coordinates of all hydrophones deployed on the bottom of the forebay

Periods of consistent powerhouse operations will be advantageous to the analysis of data on fish behavior, passage and facilitate comparisons of output from the Numerical Fish Surrogate simulation model. Stable powerhouse operations at turbines 1-7 would be advantageous in post-season simulations using a Computational Fluid Dynamics model.

LIST OF KEY PERSONNEL AND PROJECT DUTIES

Kenneth Cash (USGS) – Principal investigator, technical review, and budget oversight.
Noah Adams (USGS) – Principal investigator, technical review, and budget oversight.
Derrek Faber (Battelle) – Principal investigator, technical review and budget oversight.
Mark Weiland (Battelle) – Principal investigator, technical review, and budget oversight.
Dennis Rondorf (USGS) – Project Leader.
Thomas Carlson (Battelle) – Project Leader.
Rich Brown (Battelle) – Technical review.

TECHNOLOGY TRANSFER

Data collected during evaluation of prototype surface bypass structures will aid in the development of these structures as well as provide detailed behavioral information on juvenile salmonids near dams. We believe the results from this study will have applicability at other dams in the Columbia River Basin. Results from this study will be disseminated in the form of preliminary data reports, annual reports of research, oral presentations and briefings, and peer-reviewed journal publications.

1. Preliminary reports to the Army Corps of Engineers. A preliminary report of our findings from the spring analysis will be submitted on September 1, 2005. A similar report summarizing the summer analysis will be submitted on October 1, 2005.

2. Presentation to the Anadromous Fish Evaluation Program (AFEP) in 2005, and presentation to fisheries agencies, tribes, and the public at the Annual Research Review, 2005.

3. Draft report for 2005 anticipated by December 31, 2005 and final report by March 31, 2006.

4. Presentations to the Army Corps of Engineers staff and study review groups.

5. Presentations at professional meetings (i.e., Transactions of the American Fisheries Society) and publication of information in peer reviewed journals.

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__APPENDIX A.__

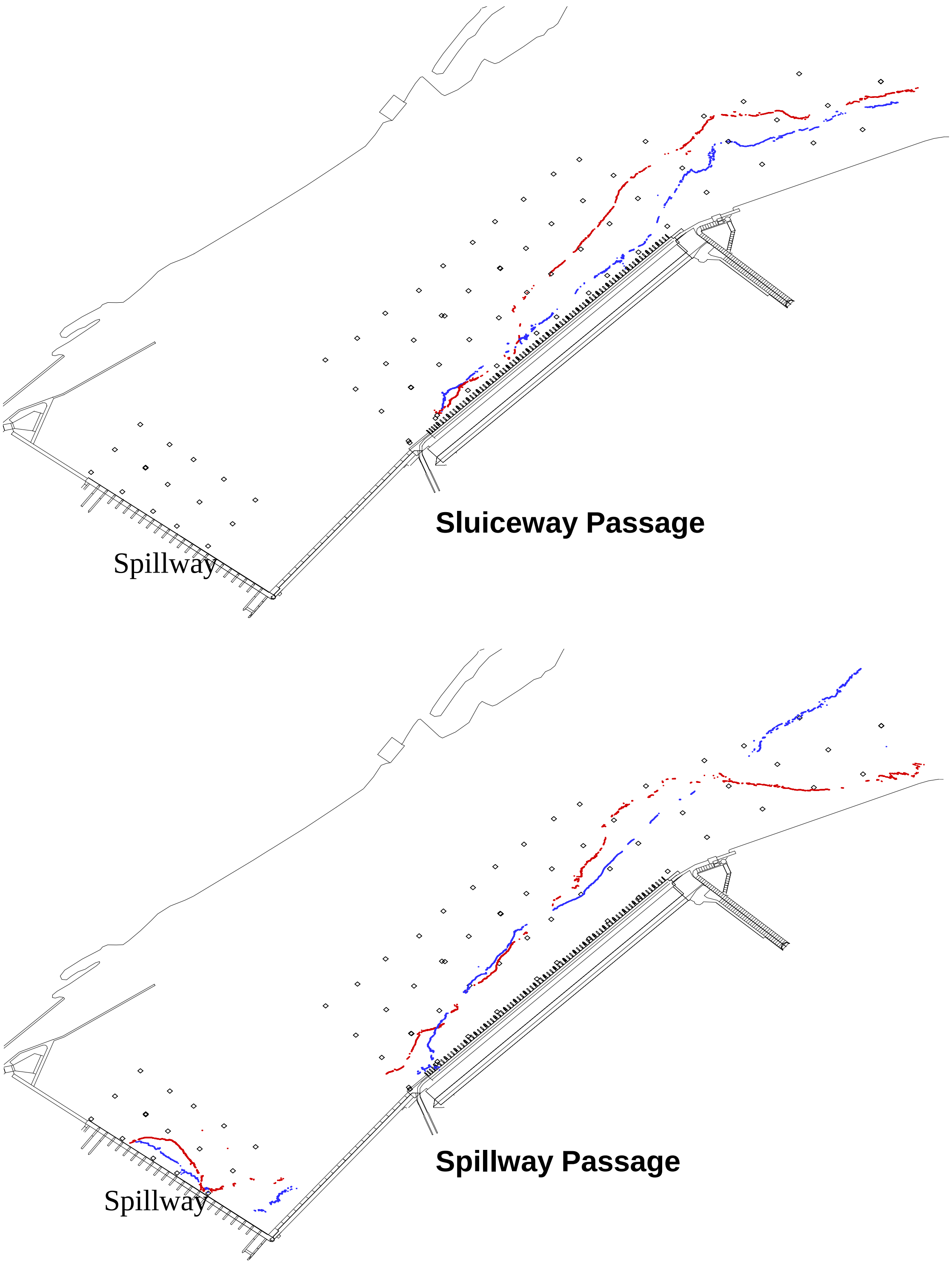

Figure 1. Sluiceway and Spillway passage behavior observed in 2004 at The Dalles Dam.

***APPENDIX B*.**

This section is provided to show an example of a 3-D telemetry system that is currently available for use in 2005.

A.1 Introduction

The HTI Model 290 Acoustic Tag Tracking System offers a means of remotely tracking fish in three dimensions with sub-meter resolution. Each digital Model 290 Acoustic Tag Receiver supports up to 16 hydrophones and receives and automatically stores tag detections for each hydrophone simultaneously. The resulting tag positions are then plotted in three dimensions over time so the user can observe the movement of each tracked fish. The Model 290 System offers much better resolution than the traditional radio-telemetry system, without depth detectability limits.

A.3 Acoustic Tag Design

Most commercial acoustic tags use frequencies between 50 and 100 kHz, and historically 74 kHz has been the most common frequency. Two major factors that affect the selection of a transmitting frequency for acoustic tags are the range of detection and size of the tag. In general, as the frequency decreases, both the size of the tag and range of detection increase.

The HTI acoustic tags are 300 kHz encapsulated, omni-directional pingers. The weight in air for each tag is 0.75 g. The transmit power level is about 143 dB uPa @ 1 m. The pulse rate is typically set to 1 pulse per sec with a transmit pulse width of 1 msec. The useful life of the tag with the aforementioned pulse rate and pulse width, once activated, is typically 12-15 days.

A.2 Tag Tracking System

The Model 290 Acoustic Tag Receiver receives on 4-16 separate channels. One channel is assigned for each hydrophone in a multiple-hydrophone array. The received signals are synchronized in order to determine time of arrival for each detected pulse. An oscilloscope can be used to display the echoes from each of the hydrophones. The arrival time of the tag pulse at each hydrophone is used to determine the location of the tag moving through the forebay. This data is saved in digital format, and a tracking program is used to track the fish in three-dimensions through the forebay.

The individual three-dimensional tracks are presented with the aid of 3-D display software. This display program is interactive, allowing the user to view individual pulses, large groups of pulses, or the entire trace for each fish. The display provides a three-dimensional background showing the coverage area including the surface collector entrances, and other features of the dam. While actively viewing fish traces within the program, the user can adjust the field of view to move spatially within the program (forward, backward, up, or down). This allows several different perspectives to be viewed for any given fish trace.

APPENDIX B.

Technical specifications for HTI Model 290 Acoustic Tag Tracking System.

Model 790 Acoustic Tags:

Dimensions:	7 mm diameter x 18 mm length for 300 kHz. Further range, longer life tags available in larger sizes.

Weight:	0.75 g.
Maximum Depth:	100 m (330 ft) standard.
Ping Rate:	Field programmable: 1 ping/sec standard (faster and slower ping rates available)
Tag Useful Life:	>14 days standard with 7 mm x 18 mm, 300 kHz tag
Detection Ranges:	For 300 kHz tags in freshwater: 300 m w/90^o hydrophone, 600 m w/15^o. For 72 kHz tags in freshwater: 800 m w/90^o hydrophone, 1600 m w/15^o. Three-dimensional tag tracking ranges approx. 50-75% of detection ranges.
Individual ID:	Individual tag identification with up to 250 unique codes.

Model 590 Acoustic Hydrophones:

Dimensions:	69 mm diameter x 140 mm length for 300kHz.
Frequency:	300 kHz. Optional frequencies available.
Beam Width:	180^o beam width standard. Optional 77^o , 15^o and 3^o beam widths available.
Maximum Depth:	50 m (160 ft).
Hydrophone Cables:	Model 690 Hydrophone Cables available in 9-305 m (30-1000 ft) lengths std.
Armored Cables:	Model 696 Armored Hydrophone Cables are steel reinforced for strength and durability and are available in 9-45 m (30-150 ft) lengths.

Model 290 Digital Acoustic Tag Receiver:

Power Supply:	120-220 VAC.
Operating Temperature:	0-50^o C
Power Consumption:	Approximately 100 watts w/o PC.
Number of Hydrophones:	Each Model 290 Acoustic Tag Receiver can optionally log data from up to 16 hydrophones simultaneously.
Data Displays:	Three-dimensional and two-dimensional displays of fish tracks over time are available. The user can control view rotation and speed of playback for each tag track.
Data Recording:	Digital Data Tape Interface and optional Digital Audio Tape (DAT) recorder directly record the digitized sample data, permitting complete reconstruction of the raw data.
Computer Requirements:	Pentium PC 300 MHZ w/Windows 95/98. 64 MB RAM, laptop recommended.

APPENDIX C.

STUDY SITE AND RELEASE LOCATION

The 3-D coverage area for a five system hydrophone array will be the entire length of the powerhouse and spillway (Figure 1). Hydrophones will be placed at about 120 m intervals along the face of the structure and in open water. Based on 3-D tests at Lower Granite Dam we expect coverage to extend a minimum of 50 m outside the baseline of the hydrophone array.

A potential release site for tagged fish is located in the John Day Dam tailrace. This location is near mid-channel and may maximize detection of tagged fish within the hydrophone array. Based on previous radio-telemetry studies above The Dalles Dam we expect to contact about 90-95% of the tagged fish.

DETECTION AND PASSAGE METRICS

The following metrics will be calculated to determine detection and passage efficiencies as they relate to project operations and environmental conditions:

$$FPE = \frac{\text{\# fish last detected at spillway + \# fish last detected at sluiceway}}{\text{\# fish last detected at spillway + \# fish last detected at sluiceway + \# fish last detected at turbines}}$$

$$SPE = \frac{\text{\# fish last detected at spillway}}{\text{\# fish last detected at spillway + \# fish last detected at sluiceway + \# fish last detected at turbines}}$$

$$SLPE = \frac{\text{\# fish last detected at sluiceway}}{\text{\# fish last detected at spillway + \# fish last detected at sluiceway + \# fish last detected at turbines}}$$

$$\text{Detection Efficiencies} = \frac{\text{\# fish detected by hydrophone array}}{\text{\# fish tagged and released}}$$

$$\text{Sluice Efficiency related to the entire powerhouse } (R_{all}) = \frac{\text{\# of fish going into sluice}}{\text{Total \# of fish passing through powerhouse}}$$

$$\text{Sluice Efficiency related to powerhouse units 1-5 } (R_{1\text{-}5}) = \frac{\text{\# of fish going into sluice}}{\text{\# of fish passing units 1-5}}$$

$$\text{Sluice Entrance Efficiency related to \# fish within 10 m of sluice} = \frac{\text{\# of fish going into sluice}}{\text{\# of fish within 10 m of sluice}}$$

$$\text{Sluice Entrance Efficiency related to \# fish within 5 m of sluice} = \frac{\text{\# of fish going into sluice}}{\text{\# of fish within 5 m of sluice}}$$

$$\text{Sluice Entrance Efficiency for fish approaching} < 12 \text{ m deep } (EE < 12) = \frac{\text{\# fish going into sluice} < 12 \text{ m deep}}{\text{\# of fish within 10 m of sluice and} < 12 \text{ m deep}}$$

$$\text{Sluice Entrance Efficiency for fish approaching} > 12 \text{ m deep } (EE > 12) = \frac{\text{\# fish going into sluice} > 12 \text{ m deep}}{\text{\# of fish within 10 m of sluice and} > 12 \text{ m deep}}$$

APPENDIX C.

FISH BEHAVIOR

Fish behavior data from the 3-D system will be post-processed and reduced to x,y, and z coordinates (State Plane coordinate system). Biological data will then be merged with hydraulic data and dam operations and environmental data to form two data sets. The first will describe fish behavior by categorizing entire fish tracks and the second will include individual vectors that make up the fish tracks. The grid method for fractal dimensions (fractal D) described by Sugihara and May (1990) will be used to develop a relative index to fish path complexity. This metric describing fish travel paths will be compared to project operations and environmental conditions to identify operational scenarios that influence fish travel paths. Generally, the index for a two-dimensional path ranges between 1 and 2 with one being the least complex fish path (a straight line) and two being the most complex fish path (a line that fills the plane).

Three-dimensional fish tracks will be analyzed for volumetric trends in fish approach velocity, residence time, fish depth, average turning angle, average direction of travel, average directional difference between flow vectors and fish vectors, Preliminary analysis results will be used to identify important factors that most influence fish behavior. These results will then be used to develop predictive equations describing fish behavior.

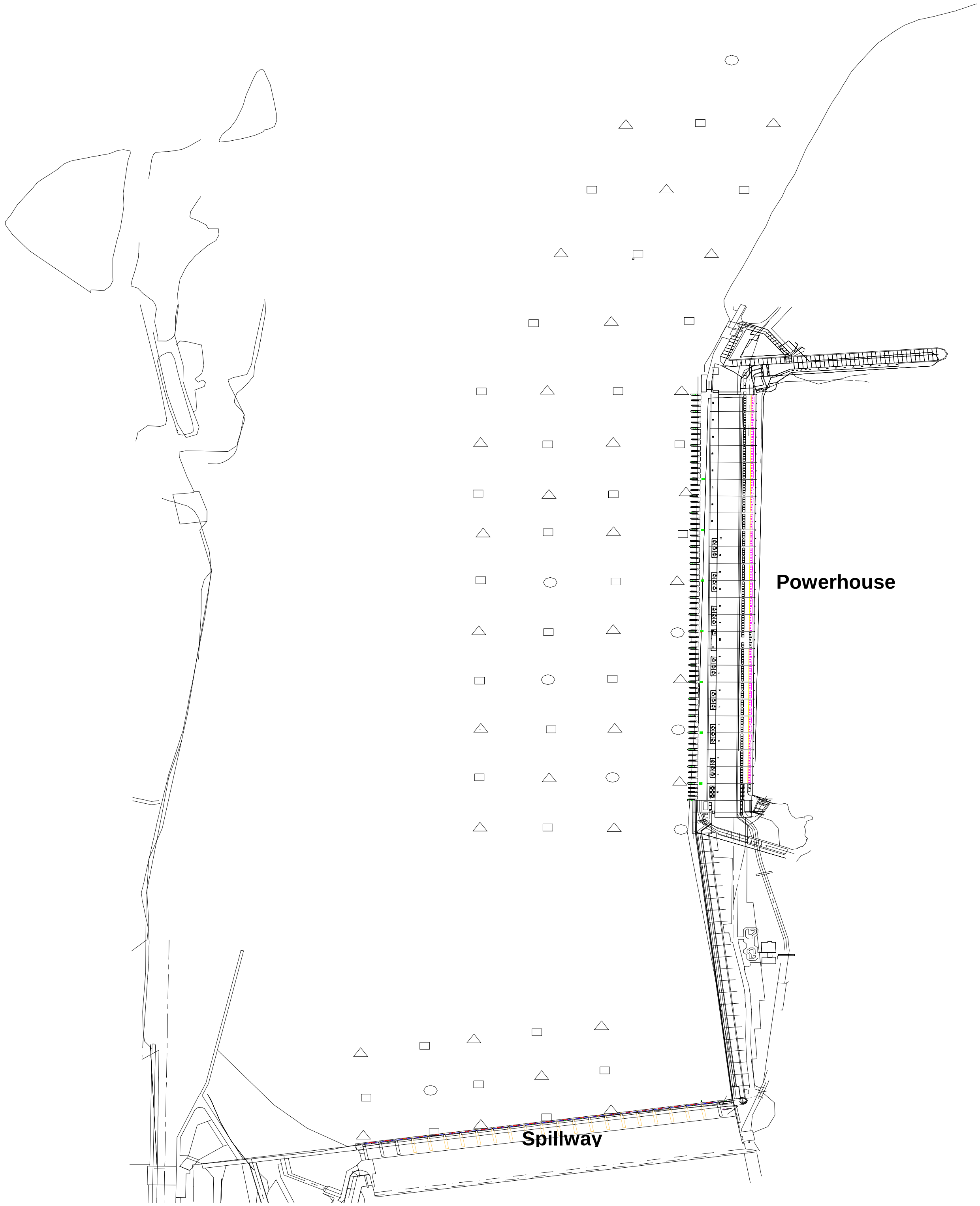

Figure 2. Hydrophone array we propose to deploy upstream of The Dalles Dam in 2005.